

## 1 CLAIMS

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3 What is claimed is:

1 1. A method for performing concurrent mark-sweep garbage collection,  
2 comprising:  
3 receiving an application;  
4 executing the application in at least one thread;  
5 determining if available space in a heap falls below a threshold;  
6 performing mark-sweep garbage collection, concurrently while executing  
7 the application, in a heap block of the heap using a first bit vector, a second bit  
8 vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap  
9 block, if the available space falls below the threshold; and otherwise,  
10 continuing executing the application and monitoring if the available space  
11 in the heap falls below the threshold, until the execution of the application is  
12 complete.

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1 2. The method of claim 1, wherein the heap comprises at least one heap  
2 block.

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1 3. The method of claim 1, further comprising initializing a concurrent  
2 mark-sweep garbage collector.

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1 4. The method of claim 3, wherein initializing the concurrent mark-sweep  
2 garbage collector comprises setting each bit in the first bit vector and the second  
3 bit vector to 0, and pointing the mark bit vector pointer to the first bit vector and  
4 the sweep bit vector pointer to the second bit vector.

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1 5. The method of claim 1, wherein performing mark-sweep garbage  
2 collection comprises:  
3 invoking at least one garbage collection thread to trace live objects in the  
4 heap block concurrently while executing the application; and

5           reclaiming storage space occupied by objects other than the live objects  
6   in the block concurrently while tracing the live objects in the block and executing  
7   the application.

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1           6. The method of claim 5, wherein tracing the live objects in the heap  
2   block comprises parallel marking the live objects by at least one garbage  
3   collection thread.

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1           7. The method of claim 6, wherein parallel marking the live objects  
2   comprises setting bits corresponding to starting addresses of the live objects in a  
3   bit vector pointed to by the mark bit vector pointer to 1, by the at least one  
4   garbage collection thread.

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1           8. The method of claim 5, wherein reclaiming the storage space occupied  
2   by objects other than the live objects in the heap block comprises sweeping the  
3   heap block to make the said storage space allocable by using a bit vector  
4   pointed to by the sweep bit vector pointer.

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1           9. The method of claim 6, further comprising toggling a bit vector pointed  
2   to by the mark bit vector pointer with a bit vector pointed to by the sweep bit  
3   vector pointer after marking the live objects in the heap block is complete.

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1           10. The method of claim 8, further comprising setting the bit vector back  
2   to 0 after completing sweeping the heap block.

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1           11. The method of claim 1, further comprising performing another cycle of  
2   concurrent mark-sweep garbage collection when available space in the heap  
3   falls below the threshold again.

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1           12. A method for automatically collecting garbage objects, comprising:  
2   receiving a first code;

3           compiling the first code into a second code;  
4           executing the second code in at least one thread; and  
5           automatically performing mark-sweep garbage collection using bit vector  
6 toggling, concurrently with the executing second code, to ensure there is storage  
7 space available for executing the second code.

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1           13. The method of claim 12, wherein automatically performing mark-  
2 sweep garbage collection using bit vector toggling comprises detecting if  
3 available space in a heap falls below a threshold and invoking the concurrent  
4 mark-sweep garbage collection when the available space falls below the  
5 threshold.

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1           14. The method of claim 13, wherein the heap comprises at least one  
2 heap block.

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1           15. The method of claim 13, further comprising using two bit vectors for a  
2 heap block, one for marking and the other for sweeping, and toggling the two bit  
3 vectors after marking phase for the heap block is complete.

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1           16. A system for concurrent mark-sweep garbage collection, comprising:  
2 a root set enumeration mechanism to enumerate references to live  
3 objects in a heap;

4 a live object tracing mechanism to parallel trace live objects in a heap  
5 block and mark the live objects in a first bit vector pointed to by a mark bit vector  
6 pointer in the heap block, concurrently with execution of an application; and

7 a garbage sweeping mechanism to sweep storage space occupied by  
8 garbage objects to make the storage space allocable using a second bit vector  
9 pointed to by a sweep bit vector pointer in the heap block, concurrently with the  
10 execution of the application and live object marking.

1           17. The system of claim 16, further comprising a bit vector toggling  
2 mechanism to toggle the first bit vector pointed to by the mark bit vector pointer  
3 and the second bit vector pointed to by the sweep bit vector pointer in the heap  
4 block.

1           18. The system of claim 16, wherein the live object tracing mechanism  
2 comprises:

3           a live object search mechanism to parallel search live objects in a heap  
4 block by at least one garbage collection thread;

5           a live object marking mechanism to parallel mark the live objects in a bit  
6 vector stored in the heap block by the at least one garbage collection thread;

7           a live object scanning mechanism to parallel scan any objects reachable  
8 from the live objects in the heap; and

9           a conflict prevention mechanism to prevent more than one garbage  
10 collection thread from marking the same object.

1           19. A managed runtime system, comprising:

2           a just-in-time compiler to compile an application into a code native to an  
3 underlying computing platform;

4           a virtual machine to execute the application; and

5           a garbage collector to trace live objects, mark the live objects in a first bit  
6 vector pointed to by a mark bit vector pointer in a heap block of a heap, and  
7 toggle the bit first vector pointed to by the mark bit vector pointer with a second  
8 bit vector pointed to by a sweep bit vector pointer at the end of marking phase,  
9 concurrently with execution of the application.

1           20. The system of claim 19, further comprising a garbage sweeping  
2 mechanism to sweep storage space occupied by garbage objects to make the  
3 storage space allocable using a bit vector pointed to by the sweep bit vector  
4 pointer, concurrently with the execution of the application and live objects  
5 marking.

1           21. The system of claim 19, wherein the garbage collector comprises:  
2           a live object marking mechanism to parallel mark the live objects in the  
3 first bit vector pointed to by the mark bit vector in the heap block of the heap; and  
4           a bit vector toggling mechanism to toggle the first bit vector pointed to by  
5 the mark bit vector pointer and the second bit vector pointed to by the sweep bit  
6 vector pointer.

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1           22. A computer-readable medium having stored thereon a data structure  
2 comprising:

3           a first field containing a first pointer pointing to a mark bit vector in a heap  
4 block of a heap;

5           a second field containing a second pointer pointing to a sweep bit vector  
6 in the heap block;

7           a third field containing a first bit vector representing at least one of  
8 marking and sweeping statuses of objects stored in the heap block; and

9           a fourth field containing a second bit vector representing at least one of  
10 marking and sweeping statuses of objects stored in the heap block.

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1           23. The computer-readable medium of claim 22, wherein the data  
2 structure is stored in a header area of the heap block of the heap.

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1           24. The computer-readable medium of claim 22, wherein the first pointer  
2 is initially pointed to the first bit vector and the second pointer is initially pointed  
3 to the second bit vector, when garbage collector is initialized; and the first bit  
4 vector and the second bit vector are toggled after the heap block is marked.

1           25. An article comprising: a machine accessible medium having content  
2 stored thereon, wherein when the content is accessed by a processor, the  
3 content provides for performing concurrent mark-sweep garbage collection by:  
4           receiving an application;  
5           executing the application in at least one thread;

6           determining if available space in a heap falls below a threshold;  
7           performing mark-sweep garbage collection, concurrently while executing  
8 the application, in a heap block of the heap using a first bit vector, a second bit  
9 vector, a mark bit vector pointer, and a sweep bit vector pointer in the heap  
10 block, if the available space falls below the threshold; and otherwise,  
11           continuing executing the application and monitoring if the available space  
12 in the heap falls below the threshold, until the execution of the application is  
13 complete.

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1           26. The article of claim 25, wherein the heap comprises at least one heap  
2 block.

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1           27. The article of claim 25, further comprising content for initializing a  
2 concurrent mark-sweep garbage collector.

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1           28. The article of claim 27, wherein content for initializing the concurrent  
2 mark-sweep garbage collector comprises content for setting each bit in the first  
3 bit vector and the second bit vector to 0, and pointing the mark bit vector pointer  
4 to the first bit vector and the sweep bit vector pointer to the second bit vector.

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1           29. The article of claim 25, wherein content for performing mark-sweep  
2 garbage collection comprises content for:  
3           invoking at least one garbage collection thread to trace live objects in the  
4 heap block concurrently while executing the application; and  
5           reclaiming storage space occupied by objects other than the live objects  
6 in the block concurrently while tracing the live objects in the block and executing  
7 the application.

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1           30. The article of claim 29, wherein content for tracing the live objects in  
2 the heap block comprises content for parallel marking the live objects by at least  
3 one garbage collection thread.

1           31. The article of claim 30, wherein content parallel marking the live  
2 objects comprises content for setting bits corresponding to starting addresses of  
3 the live objects in a bit vector pointed to by the mark bit vector pointer to 1, by  
4 the at least one garbage collection thread.

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1           32. The article of claim 29, wherein content for reclaiming the storage  
2 space occupied by objects other than the live objects in the heap block  
3 comprises content sweeping the heap block to make the said storage space  
4 allocable by using a bit vector pointed to by the sweep bit vector pointer.

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1           33. The article of claim 30, further comprising content for toggling a bit  
2 vector pointed to by the mark bit vector pointer with a bit vector pointed to by the  
3 sweep bit vector pointer after marking the live objects in the heap block is  
4 complete.

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1           34. The article of claim 32, further comprising content for setting the bit  
2 vector back to 0 after completing sweeping the heap block.

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1           35. The article of claim 25, further comprising content performing another  
2 cycle of concurrent mark-sweep garbage collection when available space in the  
3 heap falls below the threshold again.

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1           36. An article comprising: a machine accessible medium having content  
2 stored thereon, wherein when the content is accessed by a processor, the  
3 content provides for automatically collecting garbage objects by:  
4           receiving a first code;  
5           compiling the first code into a second code;  
6           executing the second code in at least one thread; and  
7           automatically performing mark-sweep garbage collection using bit vector  
8 toggling, concurrently with the executing second code, to ensure there is storage  
9 space available for executing the second code.

1           37. The article of claim 36, wherein content for automatically performing  
2 mark-sweep garbage collection using bit vector toggling comprises content for  
3 detecting if available space in a heap falls below a threshold and invoking the  
4 concurrent mark-sweep garbage collection when the available space falls below  
5 the threshold.

1           38. The article of claim 37, wherein the heap comprises at least one heap  
2 block.

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1           39. The article of claim 37, further comprising content for using two bit  
2 vectors for a heap block, one for marking and the other for sweeping, and  
3 toggling the two bit vectors after marking phase for the heap block is complete.